Evaluating the 2016 Voting Process in Baltimore County

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BACKGROUND

News reports surrounding the 2016 Election indicated that the average voter at two precincts, Edgemere and Rodger's Forge Elementary, took one-and-a-half to two hours to complete the voting process [Table II, 1], compared to the state's goal of 30 minutes [Table II, 2]. Following the negative press attention in these precincts, the Baltimore County Board of Elections postulated that the wait times were caused by delays at the newly purchased ballot scanners. Subsequently, the Board of Elections requested that the county purchase one additional scanner for each of its 225 polling places. Purchasing that quantity of scanners would cost the county an estimated $560,000 for the equipment [Table II, 13] plus additional costs for the carts in which they are transported and substantial construction to expand the Board of Elections offices by an estimated 30% to accommodate the additional scanners.

In response to the significant estimated spend of this request, the County Administrative Office commissioned business process analysts in the County Office of Information Technology's (OIT) internal consulting group, Operational Excellence (OpEx) to conduct an analysis of Baltimore County's 2016 General Election voting process.

The team was tasked with three objectives:
1) Identify the cause of reported significant wait times in specific and sporadic Baltimore County precincts
2) Assess the positive and negative effects of increasing the number of Election Systems & Software DS200 optical scanners available to Baltimore County precincts to determine the right quantity of scanners at each precinct
3) Report on any additional operational findings and make recommendations for overall operational improvement

All three objectives were designed to meet the overall goal of reducing voter wait time in the most efficient and effective way possible to be able to make significant improvements while minimizing the cost to Baltimore County taxpayers.

EXECUTIVE SUMMARY AND CONCLUSIONS

The first objective of the consulting team was to identify the cause of reported significant wait times in specific and sporadic Baltimore County precincts. The below matrix lists the causes and recommendations surrounding this first objective.

Cause of delay	Recommendations
Under-performing scanners that cause high percentages of misfeeds	1. Request that the manufacturer, ES&S replace or repair the under-performing scanners
High percentage of voters choosing to not vote for any categories on page 2 and subsequently taking longer at the scanner while they read and respond to the prompt.	2. Implement more robust scanner judge training to prepare voters for voter protection prompts and how to respond
Precincts at a high-risk for extreme delays have broad impacts on voter confidence.	3. Operational Excellence and County OIT staff will be made available for workflow monitoring during the 2018 Election. 4. The County requests that ES&S provide local support staff for the 2018 Election
Lack of problem escalation when a significant problem occurs	5. Formalize escalation thresholds in terms of exceptions per hour that indicate a problem that needs support or replacement of scanners 6. More detailed, standard work should be created and Election Judges should receive additional training [see Problem 3, pg 16].
After operational improvements are made, some precincts are still estimated to have higher demand than their current resource allocation can handle	7. Purchase 52 additional scanners for both permanent deployment and backup contingency 8. Deploy 91 additional pollbooks (already owned by the county)

For more detail on these recommendations, see the **Problems** section beginning on page 14.

The second objective was to evaluate the positive and negative effects of deploying 2 scanners to every polling place in the county. As shown by the machine log analysis and scanner testing, a high percentage of scanners are not performing to an acceptable standard. Additionally, the acquisition of approximately 250 additional scanners is very costly to taxpayers. There is a significant concern that the majority of precincts do not need additional scanners – particularly after the under-performing scanners are repaired or replaced by the manufacturer. Once poor performing scanners are addressed and additional scanners are purchased for the 47 precincts that would truly benefit from a scanner capacity increase, the county will see the same or better results with significant capital expenditure savings.

The third objective was to identify operational improvements that would benefit the election process to reduce voter wait times. Recommendations number 3 and 4 to improve overall customer services work and improve systemic problem identification and resolution will combine with scanner repair and targeted increased resource allocation to make the election process as positive as possible for Baltimore County voters.

METHODOLOGY AND PERFORMANCE BASELINING

In order to understand the election process, the consultant team undertook several methods of analysis. That analysis research consisted of:

1) Staff from the Baltimore County Board of Elections were interviewed and the overall election process was documented.
2) Secondary research was performed utilizing year-after-year reports researched and compiled by the University of Baltimore's Schaefer Center for Public Policy.
3) Machine logs from the poll books and ballot scanners from Election Day 2016 were examined to assess work times, voter arrival patterns and rates of errors or exceptions in the processes.
4) Preliminary findings, including scanner performance concerns, were presented to representatives of both the Baltimore County and Maryland State Boards of Elections as well as the vendors who manufacture the ballot scanners and print the ballots. Vendors and government agencies provided industry experience.
5) OIT underwent testing of both the highest and lowest performing scanners from the 2016 Election by re-scanning a sample of voted ballots from the general election to see if similar effects could be duplicated and/or root cause uncovered.
6) The 2017 Annapolis Mayoral Primary Election was observed to verify work times spent by election judges at each station, interactions between election judges and voters, the level to which election judged adhered regarding stated policies and procedures, and areas for which stated policies or procedures did not provide sufficient guidance for election judges.
7) Additional ongoing testing and research
8) Analysis based on the other enumerated research steps.

Each of those steps is described in entirety in this section:

1. Process Interviewing Board of Elections Staff

The first step of this analysis was to interview Board of Elections Staff to determine how the process works and what their assessment of the wait conditions during the 2016 election was. This content led the consulting team to divide process research into the major steps each voter undertakes on Election Day:

a) Voter check-in: which utilizes a device called a poll-book to look-up voter information and print the voter authority card that the voters carry to each subsequent station.
b) Ballot issue: where the voter authority card is checked and the voter is provided a ballot and privacy sleeve to keep the ballot in. In Maryland Presidential and Gubernatorial Elections (both primaries and generals), it is common for ballots to be two-pages long. Ballots are printed with perforated stubs that have serial numbers on them; the ballots are separated from the stubs at this ballot issue table by election judges.
c) Voting: where voters are provided a booth to mark their ballot.

d) Scanning: where the voter authority card is collected and voters themselves scan their ballots. This is done by voters, not election judges, for the sake of voter confidence; voters know by the time they leave their polling place that their ballot has been cast and vote counted. If the voter has made an error (such as voted for more candidates than is permitted in a category or marked the ballot in a way that the scanner cannot read), they will be notified automatically by the scanner and be given an opportunity to correct the error either on their existing ballot or a new one.
e) The team also looked at the process at a secondary check-in station, where provisional ballots are issued for voters that are either not yet registered or have come to a different polling place than the one at which they are registered.

In analyzing this data, the primary concern the consulting team focused on was voter waiting times. In a multi-step process like this, it is almost impossible for all process steps to move at exactly the same speed. As a hypothetical example, if step A moves faster than step B, then a waiting line will accumulate at step B. The science of waiting lines and how they move is called queueing theory [Table I, A], and the consulting team used this methodology to examine what factors in the election process would contribute to voter waiting.

In a multi-step process like this, the total throughput capacity (how fast a voter moves through all four stations) is constrained by its slowest step. As this analysis continues into discussion of problems across the county's precincts, it will look at a precinct's demand (voters arriving per hour) with respect to its capacity (voters able to be processed per hour). In order to do so, queueing theory requires measured performance data regarding how frequently people arrive and how long it takes to serve them at each station. In order to obtain this information, the consulting team engaged in the next two phases of research and analysis.

Additionally, in order to describe the overall capacity findings of the four stations (including the scanner), this paper will use precinct 014-008 (which polls at McCormick Elementary School) as an example. This precinct was chosen due to a combination if its size (with voter turnout in the 95th percentile county-wide) and average level of scanner performance. As a polling place, McCormick Elementary served 1570 voters on Election Day 2016 [Table II, 4]. It is allocated 4 pollbooks at check-in, 2 election judges issuing ballots and privacy sleeves, 17 voting booths and 1 scanner [Table II, 5].

2. Secondary research using published papers from the University of Baltimore's Schaefer Center for Public Policy

For several years in a row, UB's Schaefer Center has done a study on the State of Maryland's elections. The 2016 study provided the consulting team with base data regarding how frequently voters arrive at polling places and how long it takes for voters to be processed through check-in, ballot issue, and the voting booth stations [Table II, 6]. These data were used preliminarily and were later verified and refined with observation and primary research of a live election. This paper will describe overall capacity of each process step at that point.

3. Analyzing Machine Logs from Election Day 2016

The Board of Elections provided machine logs from both the pollbooks used at check-in and the DS200 scanners. These data provided estimates of how frequently voters arrived at each precinct and a portion of how much time was spent at the scanners.

Most importantly, these data revealed that not all scanning sessions ended as expected. Each page can experience one or more of the following outcomes:

1. The scan occurs correctly and the image is stored. This is the ideal outcome and indicates no unexpected items occurred.
2. The scanner detects a voter action that it considers abnormal and asks the voter if they would like to correct that item. The manufacturer refers to these as "voter protection" exceptions and they include things like:
    a. Voting for more candidates than a category allows.
    b. Submitting a blank page. Most frequently this is the second page that includes down-ticket races and issue questions that some voters skip [Table I, B], but could also occur if a voter marks a ballot too lightly and the scanner does not detect the marks.
    c. Scanning a ballot that has an unreadable mark.

    When these conditions are detected, the scanner asks the voter if he/she would like the ballot returned so a correction can be made before casting his/her vote. If the voter declines that option, his/her ballot will be cast as is.

    The most common occurrence of this outcome is item "b" – voters submitting a blank second page. Roughly 10% of total voters received a voter protection message; the total number of voters scanning a blank page was more than those who over-voted and those who wrote an unreadable mark combined.
3. The ballot misfeeds and is returned to the voter, either indicating the ballot was removed during scanning or prompting the voter to re-insert the ballot in the opposite direction. This instruction occurs as an attempt to solve issues that may cause a ballot from not being oriented properly within the optical scan image. An example of this is: if the ballot is separated from its stub improperly, the scanner may not find the orientation boxes that it uses to match ballot markings to candidates.
4. There is a paper jam and the ballot cannot feed through the scanner.

These ballot scan outcomes are significant because they impact the amount of time it takes for a voter to scan both pages. Outcomes 2-4 above can take two- to three-times longer than outcome 1; when those outcomes happen frequently, it can significantly decrease the number of voters that can be processed through a scanner in an hour [Table 1, C].

4. Preliminary scan outcome findings were compiled and presented to Board of Elections and Vendors

At present, the certifying agency that the state of Maryland chose to evaluate their system is the U.S. Elections Assistance Commission [Table II, 11]. However, the EAC's hardware and software requirements, the 2005 Voluntary Voting System Guidelines (v 1.0) [Table II, 7], focus primarily on voter accessibility and accuracy of votes captured, not voter capacity. As such, the consulting team needed to devise a reasonable capacity guideline against which to measure the scanners in Baltimore County's possession. This was done in respect to the aforementioned potential scanning outcomes. Since voter protection messages are a result of voter behavior, not scanner performance, those outcomes were excluded. Paper jams were uncommon, so those were also excluded. Misfeed exceptions, however, are pervasive and are the focus of scanner performance analysis.

The scanners in use throughout Maryland are called DS200 (manufactured by a company called ES&S – Elections Systems & Software). To start this analysis, the consulting team looked at the frequency at which misfeed exceptions were experienced in the 2016 Election (the first election in which Maryland utilized the DS200 scanners). Each precinct (except one) was allocated a single scanner [Table II, 5]. In a situation like this, the expectation is that each scanner should perform similarly. However the consulting team found that only 30.1% of scanners experienced fewer than 1 in 40 voters receiving misfeed exceptions. The rate of 1 in 40 voters receiving these results is not exceptional performance, but it is adequate. At a precinct like McCormick Elementary School, that's a delay for this type of issue every 20 minutes. The remaining 69.9% precincts fell into two performance levels:

- 46% experienced misfeeds between 1 and 40 and 1 in 20 voters. This is poor performance; a busy **precinct would experience these exceptions (and subsequent delays) every 11 minutes.**
- 23.9% experienced significant performance problems with misfeed exceptions more frequently than 1 in 20 voters. **The worst precincts saw misfeeds in one out of every 4 voters (or once every 2 minutes and 15 seconds).**

Frequency of Misfeeds	**Number of Precincts**	**% of Precincts**
Less than 1 in 40 voters	68	30.1%
Between 1 in 40 and 1 in 20 voters	104	46%
More than 1 in 20 voters	54	23.9%

These findings were presented to the manufacturer via their tech support line and, initially, the consulting team was informed that this type of misfeed exception on this large and widespread of a scale is likely caused by problems in the way the ballots were printed. At that point, the consulting team began to examine the print specifications and performance of the ballot printing vendor, Single Point Sourcing (SPS).

Over the course of that research, the consulting team scheduled a meeting to present preliminary findings to representatives from the Maryland State Board of Elections, the Baltimore County Board of Elections, Single Point Sourcing (Maryland's ballot printing vendor) and Elections Systems & Software. After presenting the above findings regarding the frequency of errors, a representative from ES&S's product development division gave a presentation with the counter-argument that misfeed exceptions are caused by voter error; behavior such as holding the ballot too long after the scanner's paper path grabs the ballot to feed it will have that effect. The representative asserted that because the misfeeds are caused by voters (and not by defects in the scanner or the ballot), these exceptions cannot be controlled or eliminated.

As the collaborative meeting with all parties concluded, the consulting team coordinated two concerted efforts to gain more insight into both the scanner performance question (and root cause of the exceptions) and overall voting system capacity. Those two efforts were:

a) The consulting team would directly test scanners and ballots that experienced poor performance and high performance during the election.
b) The consulting team would observe a Mayoral Election in Annapolis to observe how the voting process behaves live and to record more data surrounding each station's capacity.

5. Scanner and Ballot Testing

The OIT consulting team proposed the following test to evaluate the assertion made by ES&S that the high quantity of misfeed exceptions were caused by the way voters were feeding ballots into the scanners. The following methodology and results will disprove that assertion and counter that the high exception rate was caused by certain machines not performing as expected.

1. **Test Subject Selection:** OIT selected 2 precincts to use to conduct tests:
   a. 008-003, Warren Elementary School – Warren was selected as an example of a high-performing precinct. During the 2016 Election, this precinct experienced an average of 1 in 384 voters (with a standard deviation of 24 voters) experiencing re-insert exceptions.
   b. 001-012, Catonsville Middle School -- Catonsville was selected as an example of a low-performing precinct. During the 2016 Election, this precinct experienced an average of 1 in 4.3 voters (with a standard deviation of 16 voters) experiencing re-insert exceptions.
   OIT requested that Baltimore County Board of Elections pull the scanners from these precincts and a sample of voted 2016 ballots from each.

2. **Test Method:** The primary goal of these tests was to eliminate voter behavior as a variable that could contribute to the re-insert exceptions. As such, OIT conducted a controlled experiment in which ballots from each precinct were re-scanned on their original scanners by county employees whose intent was to scan as properly as possible.
   a. **Phase 1:** Initially, the testers scanned 450 ballots through the home precinct's scanner to replicate, as closely as possible, the conditions present on the day of the 2016 General Election with the only change being the replacement of voters with OIT professionals to scan ballots.
   b. **Phase 2:** In Phase 2, one additional variable was added by re-scanning the original 450 ballots from the Phase 1 test in the opposing precinct's scanner. With voter behavior eliminated in the first phase of testing, this second phase evaluated the impact of ballot image design and ballot printing. If there was a problem with the ballots themselves, the re-insert rate would have risen in 008-003's scanner when it scanned 001-012's ballots.
   c. **Timing and Behavioral Observations:** In addition to counting the quantity of errors, the OIT team also timed how long it took to scan ballots to get a feel for scanner capacity and did moderate testing on whether errors could be induced by a) feeding pages in alternate directions, b) feeding pages slightly askew (as much as is allowable by the scanner guides) and c) holding onto the ballot after the paper feed process started.

3. **Results:** Overall, the test results indicated that **neither voter behavior nor ballot image design nor ballot print quality were causing the significant quantity of re-insert misfeed exceptions**. The below detail will describe all contributing factors.
   a. **Contributing Factors: Ballots** – When ballots from either precinct were tested on precinct 008-003's scanner, zero re-insert exceptions were experienced. In addition to the standard testing, the OIT team attempted to force a re-insert exception to occur, but was only able to do so by either holding the ballot VERY strongly while it fed or inserting a ballot before the prior finished feeding through.
      Additionally, when ballots from either precinct were tested on precinct 001-012's scanner, a significant re-insert exception rate (29.6% and 31.2%) was experienced.
      This consistency, regardless of which ballots were used, indicates that neither ballot image design or ballot print quality were a contributing factor to the error rate.

   b. **Contributing Factor: Voters** – One of the primary methods of evaluating contributing factors in this test was to eliminate voter behavior variability (in other words, to standardize the way ballots were being fed through the scanner to see if the error rate still occurs). Scanning was only done by five different individuals who made a concerted effort to feed ballots through the scanner in a consistent manner. When each team of testers were utilizing the scanner from precinct 008-003, zero errors were experienced. Therefore, since both teams of testers experienced significant re-insert exceptions when using precinct 001-012's scanner without a change in behavior, the tests proved that voter behavior is not a contributing factor to the exceptions experienced on the day of the 2016 election.

      Furthermore, during the end of the final round of testing, since error rates had already been reproduced and confirmed, the testers began to test non-extreme variations in ballot feed behavior to attempt to force-create exceptions. Reasonable variations such as entering the ballot as crooked as the paper feed tray will allow did not duplicate the re-insert exceptions.

   c. **Contributing Factor: Scanner dust/dirt/residue** – Midway through the second round of testing, technical staff from the Baltimore County Board of Elections opened up the covers on the scanners to clean the plate glass and the rollers in the paper feed path. Following that cleaning, no change was experienced in the quantity or frequency of re-insert exceptions. This eliminated dust or dirt as a contributing cause to the high volume of re-insert exceptions.

      Additionally, the elections staff also indicated that this type of cleaning cannot be done by election judges because they are not well-trained enough, and improperly done cleaning could result in damage to the scanner.

   d. **Contributing Factor: Scanners**—Since ballot design, printing or voter behavior were not contributing factors to the re-insert exceptions, the only remaining consistent factor is the scanner itself. Because the scanners tested yielded largely similar results three times (during election day, during the first round of testing with their own ballots, and during the second round of testing with another precinct's ballots), the conclusion the OIT team arrived at is:

If a particular scanner is prone to this type of exception, it will continue to exhibit the same or similar exception rate regardless of other conditions. Similarly, a scanner that is NOT prone to these exceptions, will continue to NOT exhibit them regardless of conditions.

e. Other Observational results

i. The effect of re-inserting an errored ballot with the opposite orientation:
One additional testing parameter the testers evaluated was whether turning the ballot around was truly necessary when these exceptions occurred. This was tested by simply re-inserting all ballots with the same orientation following an exception. All ballots were accepted by the scanner on the 2nd or 3rd attempt using the same orientation as when the initial exception was received. It therefore appears that these error messages are often displayed at times when reorientation is unnecessary. The process of turning a ballot around to insert it in the opposite orientation is time-consuming, so if that action is unnecessary for the majority of errors, the overall scanner process will be faster if the scanners' firmware can be updated to instruct reorientation more discriminately. Alternately, scanner judges should know to instruct voters to, initially, re-insert the ballot in the same orientation and only reorient if a second exception occurs.

ii. Attempts to re-create voter behavior that will cause reinsert exceptions

1. Holding onto a ballot too long will only cause a re-insert exception if done very forcefully and is not likely to occur on Election Day.
2. Inserting the second ballot before the first had finished feeding through the paper track will cause a re-insert exception, but due to the speed of the paper feed, this can only be done deliberately. It is also unlikely to occur on Election Day.
3. Inserting the ballot slightly askew does not cause re-insert exceptions because the paper feed tray prevents this from occurring to an extreme degree (as it was intended to do).
4. Inserting the torn edge of ballot (even if the ballot was not torn well and either has corners missing or includes pieces of the stub that did not tear off) will not cause re-insert exceptions.

The ability for the OIT testing team to reproduce the Election Day ballot scan exception results (regardless of ballots image, ballot direction, ballot tear quality or scanning process/behavior) indicates that the high exception rates experienced from specific scanners during the 2016 Election are pervasive issues with those individual scanners. Subsequently, those issues are likely to continue to be observed until the scanners in question are fixed.

From a county-wide perspective, **more than 60% of the scanners provided by ES&S experienced a re-insert exception rate of more than 1 in 50 voters**. This means some busy precincts are likely to observe these messages between 50 and 125 times in a single election day.

6. Observation of Annapolis Mayoral Election

The final research that was done was observing a live election. This was done by the OIT consulting team by attending the Annapolis Mayoral Primary in one of the busiest polling places in the city. The team observed voting at precinct 001-001 which has the highest quantity of registered voters out of all precincts in the city and, based on turnout from the prior Mayoral Election, had the likelihood for the highest turnout (in terms of absolute voters).

The consulting team spent close to half a day observing the polling place and collected data on roughly one third of the total voters casting ballots in that polling place that day. The team recorded the time spent by voters at the check-in, ballot issue and scanning stations. Time spent in the voting booths was not observed because ballot length in a Mayoral Primary Election is much shorter than in a Presidential or Gubernatorial/midterm Election, and observations would not be comparable.

In addition to simply timing the voters at each step, the consulting team also made observations regarding the consistency of the way the election judge processes were conducted. In an event like an election, where the same small tasks are repeated many times over, small changes can have a significant impact over the course of the full event. Full capacity analysis will be discussed in the next section, but to give an example of the multiplying effect of small variations, the following is an example of the check-in station. At the observed polling place, 88% of voters took a minute-and-a-half or less to be checked in by an election judge. The fastest voters (about 23%) went through the check in process in under 50 seconds (the fastest being 37 seconds). Over the course of a full election day where a precinct may be serving 1000 voters, the difference between 50 seconds and 90 seconds would be an increase of more than 11 hours of work time between all of the check-in judges.

Two primary observations were made regarding process consistency:

First, the election judge manual is very clear and specific regarding what steps must be taken at each station with each voter. For example, the ballot issue judges must check the voter authority card before giving a voter a ballot, and a scanner judge must collect that voter authority card before letting a voter scan ballots. However, election judge training does not describe *how* the judges should do those processes [Table II, 8].

One of the best examples of the impact of this phenomenon was that at the start of the day in Annapolis precinct 001-001, the scanner judge took longer to step voters through the scanning process than expected (averaging 28.5 seconds per voter). Within the first 25 voters, however, this judge had dynamically refined his process to be able to collect the voter authority card faster and give the voters a better description of how to use the scanner. At that point, the average scanning time dropped by almost 6 ½ seconds. Again, 6 ½ seconds seems like a minor difference, but over the course of 1,000 voters in a day, that difference amounts to over an hour and 45 minutes of additional time that the scanner would be occupied by voters.

In this instance, the election judge was savvy enough to refine the process quickly to make it perform better. But in order to make a process work optimally, it should work the same regardless of the person doing the work. When the first scanner judge took a break and another judge (who did not have the benefit of the first judge's experiential learning curve) took over, the process slowed down by an average of more than 2 seconds.

Other examples of this process include judges not taking an active enough customer service role in helping voters move through the system. For election judges, this process becomes second nature. They know which station is check-in and which station comes after check-in, etc. But voters do not gain the benefit of a learning curve since they only vote twice every two years at most. For example, the consulting team observed the first voter in line at check-in not being ushered forward by an available check-in judge. In some cases, voters waited to be waved forward for as long as it should have taken to check them in.

The second item observed was a lack of escalation threshold. The term "escalation threshold" refers to defining a point when the normal way of doing things stops yielding the expected outcome and the process may need to change (or the outcome may be undesirable).

For example, 5% of voters took 3 minutes or more at the check-in station. In most cases, this was due to a question of the voter's registered precinct; many of these voters had moved but not changed their permanent address in the Board of Elections' system. In those cases, the voter can choose to either leave and go to their registered precinct to vote or be given a provisional ballot and re-register themselves in the current precinct with their updated permanent address. Regardless of the voters' choice, at the point in time when they are found to not be registered at the current precinct, they could have been escalated to an alternate station (such as the provisional ballot station or one of the chief judges) to finish the process and allow the check-in judge to continue serving other voters that do fall into the standard process.

During the 2016 General Election in Baltimore County, the Towson Student Union was another example of this phenomenon. No material scanner exceptions were present for the first eight-and-a-half hours of the day, but at 3:50pm there was a sharp increase in paper jam errors that went unresolved for the remainder of the day. There were no significant wait times experienced by voters because only 170 votes were cast at this precinct on Election Day (the majority of voters in this precinct voted absentee). But the magnitude of paper jams at this precinct was significant. There were only 382 paper jams across 225 precincts for the entire day; 13% of them happened at the Towson Student Union. Yet, when the chief judge called the Board of Elections headquarters shortly after 4:00pm, they were instructed to not utilize the scanner's backup bin process and were not provided a replacement scanner [Table II, 9]. Shortly thereafter, the chief judge called again due to the issue persisting and was told to use the backup process at that point [Table II, 9]. However, the scanner was never repaired and errors persisted for the remainder of the day. Had a clear escalation threshold been defined, this precinct would have immediately been identified to repair or replace the scanner. Furthermore, had this type of issue occurred at a busier precinct, there would have been a much more significant impact on voter wait times.

7. Additional/Ongoing Testing and Research

Because at the time of the ballot testing done by the consulting team, the specific primary root cause of misfeeds had been narrowed to a general area but not specifically determined, additional work was and (at the time of this paper's release) is still being done. The specific purpose of this research is to utilize this root cause assessment to plan the best way to prevent the phenomenon from recurring in future elections.

The first step that was done to this end was to recreate a similar testing environment with the scanner manufacturer present. On 10/25/2017, representatives from ES&S met members of the county consulting team at the Baltimore County Board of Elections Headquarters. At that time, the previous test could not be recreated exactly because the ballots from the 2 precincts that had been originally tested had, per the SBE's standard retention policy, been sent to off-site storage. As such, ES&S brought demonstration ballots to use, manually marked those ballots and loaded the election specifications onto one of the originally tested scanners. It is important to note that these demo ballots differed from the original ballots in the following ways:

- The ballot images were designed by ES&S
- The ballots were printed by ES&S
- The ballot stock was provided by ES&S
- The ballots are 3 inches shorter than Baltimore County's standard ballots (14" instead of 17")
- The ballots were not printed with stubs, so no perforated edge existed

With the demo ballots being used to test, the misfeed rate dropped dramatically (from 29-30% to 1-2%). This prompted the testers to pull voted ballots from the 2016 election from another precinct (013-009) to use as test. Misfeed rates remained low (2-3%). As a result of this change in test results, the consulting team has:

- Requested the ballots from 001-012 and 008-003 be retrieved from storage for further comparison and testing
- Scheduled plans to research the effect of
    - Power cycling/memory flushing
    - Heat sync/heat management
    - Physical movement/calibration obfuscation

On the scanning process. This research is ongoing.

8. Capacity analysis based on above research

Overall, average county-wide capacity findings are as follows:

1. Check-in: A little more than 80% of voters will be checked in by election judges in less than 80 seconds (averaging 58 seconds per voter). The other 20% of voters need more time at check-in either due to more-than-average questions or confusion about a correct polling location (often due to a recent change of permanent address). Those voters average about 2 ½ minutes for check-in. This makes the overall capacity of one poll-book around 48 voters per hour.
2. Ballot issue: Around 95% of voters should be expected to move through ballot issue station in 55-60 seconds making the capacity of one ballot-issue judge around 60 voters per hour.
3. Voting: This step in the process tends to be the most variable because election judges are less involved and voters move at their own pace (ie: some prefer to thoroughly read all questions before answering, but some come to the polling place already knowing how they want to cast their votes). Voting times commonly range anywhere from 1 to 9 minutes with an average of about 3 minutes per voter. At that rate, one voting booth has an average capacity of 20 voters per hour.

4. Scanning: the aforementioned scanner outcome exceptions greatly vary the amount of time a voter will spend at the scanner. At McCormick Elementary, 86.6% of voters experienced no unexpected outcomes (voter protection, misfeed, paper jam or otherwise). 9.2% received some type of voter protection alert. 4.2% experienced a ballot misfeed. And less than half a percent experienced a paper jam. At those rates, the average time for a voter to scan both pages of their ballot is 26 seonds – making the scanner's hourly capacity 138 voters.

Because McCormick had 4 pollbooks, 2 ballot-issue judges, 17 booths and 1 scanner, their total hourly capacity is as follows:

Station	**Resource**	**Quantity**	**Capacity per resource (voters/hr)**	**Total Capacity (voters/hr)**
Check-in	Pollbooks	4	48	192
Ballot issue	Judges	2	60	120
Voting	Booths	17	20	340
Scanning	Scanner	1	144	138

In this case, the ballot issue station is the one with lowest capacity, which makes the polling place's total hourly capacity 120 voters per hour. The reason McCormick was not one of the precincts that was featured in the news was that the maximum quantity of voters they saw in any given hour of the day was 123 voters between 6 and 7pm. In other words, McCormick's hourly volume of voters was below its hourly total capacity for the vast majority of the day.

Again, McCormick Elementary was a single example of a polling place. Once this capacity information was distilled from the various forms of data collected, it could be applied to any precinct's resourcing. Because ballot and scanner testing found that one scanner may only incur a misfeed error in 1 out of 300+ voters while another scanner may see the same error in 1 out of 4 voters, the hourly scanner capacity varied greatly in the 2016 Election. The highest performing scanners in the county could process 155 voters per hour. The lowest could only process between 115 and 120.

What the consulting team did next was to evaluate the problems reported through the news, by the Board of Elections, and primarily seen through election observation, testing, or data analysis. The following sections of this analysis will describe how the problems were examined for their impact and root cause so that mitigating recommendations could be made.

PROBLEM 1: Addressing Rodgers Forge & Edgemere

Background and Impact

The first problem documented is the aforementioned long lines at certain precincts that were reported on local news [Table II, 1]. While these occurrences of significant waiting were uncommon when compared to the rest of Baltimore County, their impact is still of concern because the constituents in those precincts were made to wait an unreasonable amount of time. Long lines at polling places are generally agreed upon as one of the primary ways a polling place can negatively affect voter turnout [Table II, 10]. Additionally, these waits were reported on the news and prematurely attributed to there being only one scanner at each polling place (save one). The remainder of this report will demonstrate

that it is unlikely that scanner allocation alone is at fault for delays. But attributing waiting lines to a factor that is identical at each polling place is a concern, because voters at other precincts could misinterpret the news and social media reporting on such anomalies, believing lengthy lines to be common experiences in other precincts. Thus, precincts reporting extreme wait times pose risks of impacting county-wide voter turnout, and steps must be taken to reduce such precincts' wait time problems (and subsequent potential impact on other precincts).

Causes

The two precincts that garnered attention in the news: 015-021: Edgemere and 009-003: Rodger's Forge both had voter turn-out of more than 1500 people on Election Day [Table II, 4]. While these are two relatively large precincts, this size alone is not enough to cause delays, since a single scanner should be able to process 1800 people in a day [Table I, D].

Some insight into the scanner delays is revealed when the page-by-page ballot results are examined. A high performing county precinct (such as 007-001, which saw more than 1800 voters) experienced 6.8% of voters triggering voter protection exceptions (primarily blank pages), 0.6% of voters receiving misfeed exceptions, 0.2% of voters with more serious issues (like paper jams) and 92.4% of voters had no scanning exceptions. This mix of scanning outcomes made the average time at the scanner 24 seconds per voter.

In comparison, Edgmere and Rodger's Forge averaged 26.3 and 27 seconds per voter (respectively). Across 1500 voters each, that represented additional scanner time of an hour at Edgmere and an hour and 40 minutes at Rodger's Forge.

Ballot testing confirmed that the misfeeds are a problem with the scanner itself. These two precincts incurred misfeeds in 1 out of every 24 and 17 voters (respectively). Had they been lucky enough to receive one of the 68 scanners that saw fewer than 1 in 40 voters receiving misfeeds, their delays would have been substantially less.

While the source of voter protection exceptions can be attributed to individual voters' choice (a voter is well within their rights to choose not to cast a vote in certain categories), the lack of consistency in observed scanner judge process or training shows that election judges can be equipped with a better process to mitigate the delays of voter protection exceptions.

Recommendations

1. The consulting team has identified 54 primary scanners throughout the county that miss one of two performance criteria during the 2016 election: Either they had more than 4% of voters receive misfeed exceptions or, based on that precinct's likely busiest hour of the day in terms of voter turnout, the scanner would not be able to process that hour's worth of voters in one hour or less. Baltimore County has alerted the Maryland State Board of Elections to those scanners of concern and has asked that the manufacturer replace or repair them.
2. Better standard work processes need to be put in place for scanner judges to help voters navigate through voter protection messages (particularly blank ballots), since those are likely to continue to be pervasive.

3. Operational Excellence and other members of County OIT staff will be made available for workflow monitoring at the precincts deemed to be at highest risk for delay during the 2018 election
4. The county requests that ES&S provide local support staff presence to be made available for the 2018 election as well

PROBLEM 2: Select Scanners with Pervasive Misfeed Problems

Background and Impact

While not every precinct's misfeeds resulted in significant delays, there were still pervasive misfeeds observed with scanners at 70% of the county's polling places. These unreliable scanners will continue to cause issues unless they are repaired or replaced, and this issue will only be exacerbated if these precincts see a significant quantity of voters arriving during a peak time of day.

Causes

Scanner and ballot testing has shown that these misfeeds are unequivocally the result of machines that are not being produced or tested with any type of consistency performance standard in mind.

Recommendations

1. (same recommendation as Problem 1) The consulting team has identified 54 primary scanners throughout the county that miss one of two performance criteria during the 2016 election: Either they had more than 4% of voters receive misfeed exceptions or, based on that precinct's likely busiest hour of the day in terms of voter turnout, the scanner would not be able to process that hour's worth of voters in one hour or less. Baltimore County has alert the Maryland State Board of Elections to those scanners of concern and asked that the manufacturer replace or repair them

It is important to note that purchasing more scanners to augment the poor performance of existing ones would help this problem, but it would do so at great cost to the taxpayer. The county finds it much more **prudent to hold the manufacturer accountable for the performance of their product rather than rewarding them for poor performance by purchasing $560,000 of additional equipment from them**.

PROBLEM 3: Lack of Clear Escalation Procedure when Problems Occur

Background and Impact

As previously described, a lack of clear escalation threshold and/or procedure creates significant variability in the time it takes voters to move through each station. That variability, in turn, results in waiting for voters.

Causes

The Election Judge manual is very clear on certain procedures and, in some cases, on what to do as a contingency if the primary procedure fails. However, it does not specify when a contingency procedure should be enacted or proved specific detail of how to perform a process the most efficient way possible.

Recommendations

5. Escalation thresholds should be quantified and communicated as a product of misfeeds or paper jams per hour. Quantities higher than the threshold should result in escalation for scanner support, repair or replacement.
6. More detailed, standard work should be created and election judges should receive documentation and/or training on:
    a. When and how to route voters at check-in who are not registered for the precinct
    b. How to use floater judges to prepare voters waiting in the scanner line for voter protection messages
    c. How to best move voters through the scanner station (particularly if their hands are full)
    d. How to best describe where to insert ballots into the scanner
    e. How to distribute "I voted" stickers in a way that moves voters away from the scanner and does not significantly occupy scanner judges' time
    f. How election judges at all stations should actively work towards the customer service goal of helping voters move through the process

PROBLEM 4: Proper Resource Allocation

Background and Impact

Once the consulting team identified technical and operational improvements that could be made, they evaluated the way election judges and technical resources (pollbooks and scanners) were allocated to precincts. Their findings, based on estimated voter wait times, did indicate that some precincts needed to be allocated more resources.

Causes

At present, precincts are allocated resources based on registered voters. It makes more sense, however, to allocate resources based on likely voter throughput capacity during the busiest time of day. In other words, most precincts see a significant peak in voter arrival either in the morning before voters go to work or afternoon (after work). If resources are allocated based on how much time it will take to process voters during the precinct's busiest time of day, the formation of major lines should be mitigated.

Recommendations

7. The consulting team identified 47 precincts that would benefit from having a second permanent scanner. That request for additional scanners was communicated to the State Board of Elections in early October 2017 so that scanners would be purchased and received by February 2018 and ready for the primary elections taking place in the spring of 2018. The county also ordered 5 additional contingency scanners that can be deployed upon request to precincts if there is a technical problem on Election Day.

This decision to add a second scanner to 47 precincts was based on 2016 voter turnout data. This estimate is considered a conservative one based on a) the fact that the 2018 is a Gubernatorial/midterm Election (which generally has lower turnout than a Presidential Election), b) the trend of voters taking advantage of early voting has seen a 10-16% drop in Election Day voting each year as voters take

advantage of early voting locations, and c) the consulting team estimates that 11% of voters will arrive within a single peak hour (the county average is 7.5%).

The decision to purchase 52 scanners (instead of an additional 235) is estimated to save taxpayers $436,085 in the cost of equipment alone. Adding to this the cost of a) the scanner transportation carts, and b) the possible renovation to the scanner storage warehouse to accommodate the additional equipment is likely to save the county more than $2 million in cost avoidance.

8. In addition to scanners, the consulting team also evaluated the pollbooks used at the check-in station. Based on the same assumed turnout methodology used to evaluate scanner resourcing, 86 precincts were found to need 1 or 2 additional pollbooks (for a total of 91 additional pollbooks placed in the field). On 10/28/2017, the Baltimore County Board of Elections reported that they have 877 pollbooks on hand. Of those 877, 688 are currently in use in the field leaving a surplus of 189. This means the needed additional 91 pollbooks can be placed while still leaving a surplus of 13% in case a pollbook breaks down. This surplus is important because the current model of pollbooks in use is no longer being produced by the manufacturer, with a newer version being tested for future deployment. Additionally, the consulting team found that 19 other precincts have one or two more allocated pollbooks than they need. If those precincts pollbooks are reduced to their needed level, it would increase the surplus to 16%. In the end, Baltimore County owns enough pollbooks to properly resource all precincts until the current model pollbook is replaced.

REFERENCES

Table I. Calculations and Methodology
The team's approach centered on the use of Erlang's Queuing Theory to calculate key metrics such as Utilization and Average Wait Time. Below are descriptions of how and where these calculations were made, as well as additional estimates and modeling techniques used by the team.

#	Reference	Explanation
A	Queueing Theory	Developed by A. Erlang in 1909. $$T_q = \left(\frac{p}{m}\right) \times \frac{u^{\sqrt{2(m+1)}-1}}{1-u} \times \left(\frac{CV_a^2 + CV_p^2}{2}\right)$$
B	Second page frequently left blank	Derived from the scanner machine logs, a time differential analysis was done on sessions resulting in a "blank ballot" record and their relations to "ballot image stored" sessions before and after. The overwhelming majority of blank ballot records were closer, in time, to a prior "ballot image stored" session, suggesting most blank pages were the second page of the ballot.
C	Impact of outcomes on scanner processing time	Observational and machine log data were used in conjunction with queuing theory to generate this comparative analysis.
D	Average Scanner Capacity	Calculated using a both observed processing times and machine log data. Crosschecked with ES&S-stated processing times.

Table II. Externally Sourced Material *A number of external sources were referenced to build the team's analysis, represented below.*		
#	**Reference**	**Source**
1	News reports on long wait times in Edgemere and Rodger's Forge Elementary	ABC 2 News – WMAR "Voters in Edgemere wait in lines extending outside, around building". Nov 8, 2016. ABC 2 News – WMAR "Long lines to vote in Baltimore County". Nov 8, 2016. https://www.youtube.com/watch?v=RFDX4En4J48
2	State goal of 30 minutes to complete the voting process	Willis, John T., JD, Dennis McGrath, PhD, Will Haller, and Kenneth Weaver. *Wait Time Observations from the 2016 Maryland Primary Election*. University of Baltimore Schaefer Center for Public Policy, 2016.
3	Cost of additional DS200 Scanners	Baltimore County Office of Budget and Finance estimate based on current contract
4	Voter Turnout Data	Voter turnout data is published on the Maryland State Board of Elections website.
5	Current Equipment Allocation	Baltimore County Board of Elections
6	UB Schaefer Center Report	Willis, John T., JD, Dennis McGrath, PhD, Will Haller, and Kenneth Weaver. *Wait Time Observations from the 2016 Maryland Primary Election*. University of Baltimore Schaefer Center for Public Policy, 2016.
7	EAC Technical Guidelines	United States Election Assistance Commission. *Voluntary Voting System Guidelines Ver. 1.0 (2005).*
8	Election Judge Manual	*2016 Election Judges' Manual*. Revised 12/01/2015.
9	Election Judge Telephone Logs	Election Judge Telephone Logs. General Election 11/08/16. Acquired from Baltimore County Board of Elections.
10	Long lines can reduce voter confidence	Charles Stewart and Stephen Ansolabehere. *Waiting in Line to Vote*. July 28, 2013.
11	Maryland State Board of Election's Certification Standards	Aumayr, P. *Election Systems and Software EVS 5.2.0.0 Certification Report*. MD State Board of Elections. 10/23/14.